Three-Dimensional Microlithography System

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We are creating a unique lithography tool capable of patterning 3-D surfaces at micron dimensions. Unusual micro-electromagnetic and micro-electromechanical structures can be created using this tool.

Twelve years ago, LLNL's Micro-electronics Program developed a quasi-3-D laser direct writing tool, called Laser Pantography, to fabricate metal interconnects on multichip modules. In addition, this tool, together with associated deposition and etching processes, allowed the program to make unique mm- and sub-mm-scale parts such as RF inductors, diamond anvils with electrode structures, NMR microcoils, micromotor stators, and magnetic relays.

The Laser Pantography tool had fundamental limitations, however, and because of the original mulitchip module application and limitations in the CAD/CAM systems of the time, the configuration could not support out-of-plane patterns more complicated than straight lines of fixed length parallel to the z-axis. Also, the workstation was out-of-date, using an operating system no longer supported.

Another limitation was that motors could not be started at exactly the same time. This meant that diagonal lines in the x-y plane, to use a simple example, were executed as stair steps. A modern motor control system would allow simultaneous movement of multiple stages so that smooth diagonals, ovals, and other shapes could be drawn.

These limitations have been addressed in this technology-base project.

We are assembling a modern, fully 3-D, sub-µm-accuracy motion system driven by a commercial CAD/CAM package. This 3-D microlithography system (3D MLS) functions as a five-axis milling machine with a focused laser as the "cutting tool." The laser does not actually cut; it exposes a photo-active substance such as photoresist, to create the desired pattern.

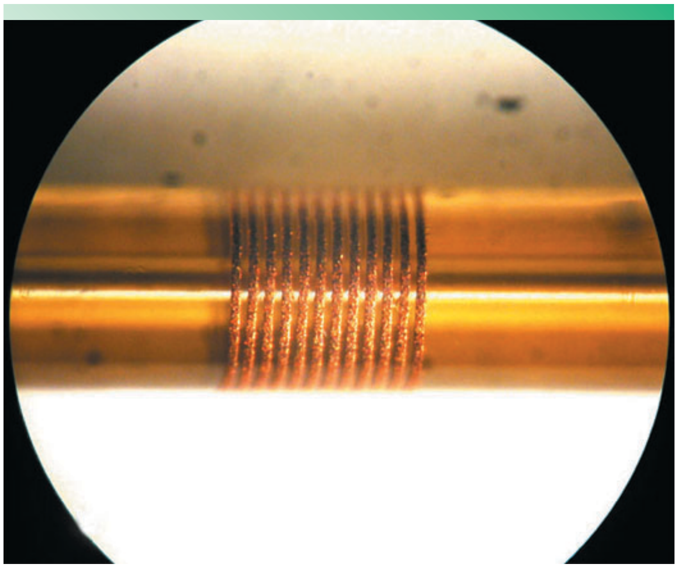
With improvements in the optical system, the "cut size" can be 1 µm. The upgrade of the 3D MLS will involve the replacement of the original custom hardware and software with a standard motion-control hardware package, together with commercially available 3-D CAD/CAM software, which is licensed to LLNL. The new software will output standard G-code, which the new hardware will be able to execute in the same fashion as a five-axis milling machine.

A true 3-D microlithography system will be the final product. It will be a unique capability, and is expected to generate considerable interest and funding. It will dramatically increase the 3-D patterning capability of the present system, making it applicable to surfaces and structures that cannot now be patterned. As technology demonstrations, we will pattern helices on < 400-µm-diameter cylindrical surfaces (for NMR and MRI applications) and simple periodic structures on spherical or elliptical surfaces of radius of order 1 mm.

In FY02 we installed new motion-control hardware, including motor amplifiers and motor controllers for up to eight degrees of freedom. A 3-D CAD/CAM package was installed, and initial handshaking software linking it to the motion-control hardware was installed. X, y and z translation stages (existing equipment) were installed and wired. Requirements for high-precision theta in x- and z-axes were ascertained, and stages with sufficient speed and precision were identified and purchased. A high-power UV argon-ion laser was procured internally and was refurbished. An optical system emphasizing a small focal spot, which can be expanded for rapid patterning of large areas, was completed, and the required components identified.

In FY03 we completed the motion system with two rotation stages. An initial version of a Visual Basic GUI front end for the PC was written. We assembled a new optical system (*e.g.*, objectives and tube lenses), which is more versatile.

Fixturing for various workpieces is also a significant issue when precise knowledge of the exact position of the part is required. We have made significant progress on holding 360-µm-diameter flexible tubes on which NMR coils are fabricated. We are now confident of our ability to fabricate 100-µm-diameter NMR tubes for DOE and DHS in the coming year.



Twelve-turn coil patterned on 360-µm-diameter capillary.